

# Solid-State Replacements for Hydrogen Thyratrons



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**M**any laboratory pulse-power applications rely on obsolete/obsolescent switching technologies such as hydrogen thyratrons and hard tubes. As the number of users erodes and the industrial base for production of these devices fades, prices have increased, lead times have lengthened, and in many cases only a single (foreign) source remains. New families and new generations of solid-state devices are becoming available that may provide viable alternatives to gas and vacuum switches. At LLNL, we are expanding our expertise in solid-state pulse switch technology to maintain our viability in pulse power.

Figure 1. Solid-state switch test-stand with data acquisition system.



## Project Goals

Our goals for FY2004 include: 1) evaluating promising commercially-available solid-state devices to prepare guidelines for future pulse-power switching applications in engineering; 2) evaluating device capabilities and limitations as they affect the ability to effectively replace thyratrons in high-power applications; 3) evaluating multiple device types to identify cost-effective solutions for gas-switch replacement; and 4) demonstrating full functionality and lifetimes in a representative LLNL application.

## Relevance to LLNL Mission

Enhancing this expertise will be beneficial to existing and future programs that require high-power switches. LLNL has many needs for high-current/high-energy capacitive discharge units, including magnetic flux compression generators; flash-lamp banks and Pockels cell drivers for lasers and NIF; pulsed high-field magnets; EM launchers/rail guns; and compact electric power conversion.

## FY2004 Accomplishments and Results

We have constructed an interlocked high-voltage test-stand with a full suite of electrical diagnostics for evaluating solid-state devices. We have also fielded a data acquisition system (Fig. 1) for efficiently capturing and analyzing waveforms; procured and evaluated multiple families of solid state devices (Fig. 2); created laser diode driver circuitry for light-triggered thyristors that will be directly applicable to new, higher power devices; demonstrated device functionality in existing LLNL pulse-power application; documented performance information for future solid-state switches; tested a light-activated thyristor trigger system/fault detection

system; evaluated magnetic-assisted switching of thyristors; explored series and parallel operation of high-power thyristors; operated solid-state switches in grounded and off-ground configurations; operated solid-state switches in linear (resistive) and nonlinear (plasma) loads; investigated the effects of high currents and high (di/dt)s on device lifetimes; and investigated failure mechanisms in solid-state devices.

Figure 3 compares solid-state vs. thyatron system complexity.

#### Related References

1. Erickson, R. W., and D. Maksimovic, Fundamentals of Power Electronics, Kluwer Academic Publishers, United Kingdom, 2001.
2. Williams, B.W., Power Electronics: Devices, Drivers, Applications and Passive Components, McGraw-Hill, New York, 1992.
3. Kassakian, J., M. Schlecht, and G. Verghese, Principles of Power Electronics, Addison-Wesley, Reading, Massachusetts, 1991.
4. Heumann, K., Basic Principles of Power Electronics, Springer-Verlag, Germany, 1986.

#### FY2005 Proposed Work

We propose to evaluate new, higher current, higher (di/dt) devices beyond manufacturers' ratings to determine suitability for pulse-power operation; test operate at higher current and short pulse duration; determine device limitations and/or failure modes; verify that our trigger system can be used with new devices; and further investigate series/parallel switching issues to obtain higher performance.

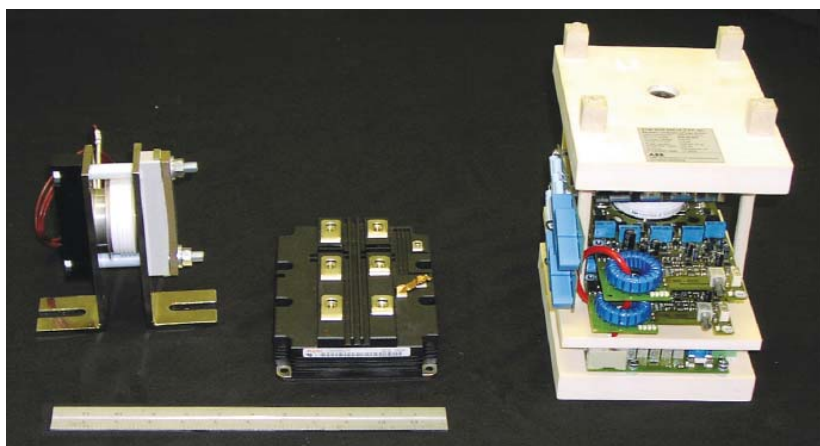


Figure 2. Solid-state devices tested and evaluated. From left to right: Eupec phase-control SCR (light-triggered thyristor); Eupec IGBT (6500-V power bricks); ABB inverter-grade reverse-conducting thyristor stack (pulse-power thyristor).

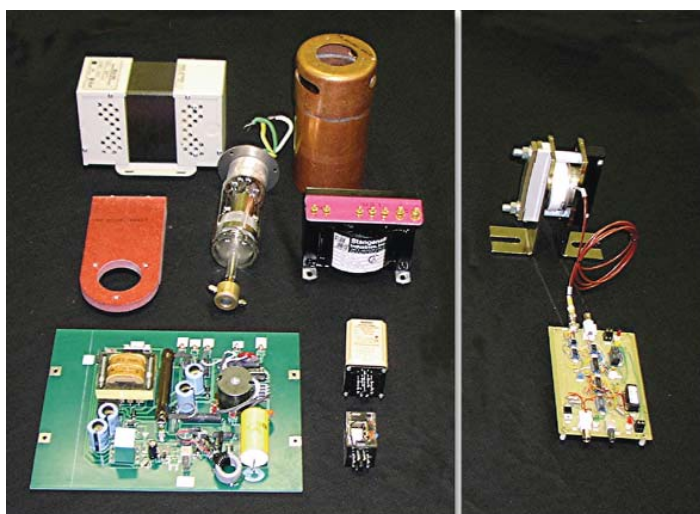


Figure 3. Solid-state vs. thyatron system complexity. Left side displays thyatron and required ancillary equipment. Right side shows an SCR and driver that replaced the thyatron in proof-of-principle testing. Solid-state switch and driver represent a 75% reduction in cost with a significant reduction in parts count and volume.